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An Analysis of Generalized Joint Hypermobility and Knee Pathology

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AN ANALYSIS OF GENERALIZED JOINT HYPERMOBILITY AND KNEE PATHOLOGY

by

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This Independent Study, submitted by Jan Lee Gustafson in partial fulfillment of the requirements for the Degree of Master of Physical Therapy for the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

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Department Physical Therapy

Degree Master of Physical Therapy

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Signature Jan L Gustafson

Date 12/10/97

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ABSTRACT

The purpose of this study is to evaluate if a relationship exists between generalized joint syndrome and knee pathology. Both of these have been found to be of increased prevalence in females. Sixty female high school seniors from eight northwestern North Dakota and northwestern Minnesota high schools were selected to participate in this study. Selection criteria consisted of prior testing for ligament laxity with a KT-1000 and for generalized joint hypermoblity syndrome. Guidelines were established and a participation survey was approved by the Institutional Review Board at the University of North Dakota. The survey form required the completion of open-ended questions regarding knee injuries. Although no statistically signficant relationship was found between joint hypermobility and knee pathology, there was a trend for those identified with hypermobility to sustain more knee injuries.

CHAPTER 1

INTRODUCTION

As women are increasing their participation in sports and physical recreation, they are gaining benefits related to increased fitness. They are also closing the gender gap in the number of sports-related injuries. The athletic injury data for sports such as basketball and soccer that are comparable between genders due to their similar playing conditions, body movements, and physical fitness requirements have shown that women and men have about the same number of overall injuries.[1-16] However, researchers have found that women athletes have a much greater risk for a knee ligament rupture or sprain.[1-2,7-16] While comparing injuries among male and female professional basketball players over two seasons, Zelisko and colleagues[2] reported that women had significantly more knee injuries and more ligament sprains. Reports from NCAA Surveillance for 1989-1990 show that females injured their anterior cruciate ligaments 7.8 times more than the male athletes.[7,9,12,15] Malone[8] also reported that the ACL injury rate in collegiate female basketball players was eight times that of males. This extreme and rapid rise in injuries of the ACL, the principal knee stabilizer, in female athletes has been reason for considerable concern recently, but no definite cause has been determined.[7-16]

A greater understanding of the factors that contribute to knee injuries is needed to prevent the injuries and provide adequate treatment to prevent re-injury. There is a great amount of research on the function of the ACL, but there are few scientific studies that focus on the cause of ACL injury. One theory is that ligament

laxity may predispose an athlete to ligament sprain. This has been a controversial issue, but one of the first studies on this subject was by Nicholas[16] who found that loose-jointed professional football players were much more likely to rupture knee ligaments than the tight-jointed players. Diaz[17] has also found an association between hypermobility syndrome and musculoligamentous injury. However, both of these studies were conducted on all male subjects. Recently, a very well-controlled research study by Woodford-Rogers et al[18] using 22 male and female athletes and 22 athletic controls who were matched by age, gender, and sport found an association between knee joint hypermobility, subtalar joint hyperpronation, and ACL injury.

Women have a higher prevalence of joint laxity, or hypermobility.[19-31] In fact, generalized hypermobility syndrome (HMS), which is characterized by joint and ligament laxity, has been shown to affect females not only more frequently but also more severely.[19-21,22-31] The evidence that young females have an increased rate of both ACL injuries and joint laxity gives merit to the hypothesis that the higher prevalence of ACL injury in women basketball athletes could be due, at least in part, to hypermobility syndrome. The purpose of this study is to evaluate whether a relationship exists between HMS and ACL injury.

CHAPTER 2

LITERATURE REVIEW

Normal joint mobility is highly variable due to its dependence on several factors: shape of bone and cartilage, muscle power and tone, and laxity of the ligaments and capsule.[25] Hypermobility, or excessive joint motion, has historically been known to medical professionals to be an interesting symptom of disorders such as osteogenesis imperfecta, Ehlers-Danlos syndrome, Marfan's Syndrome, myotonia congenita, and arthrogryposis.[19-20,22,24-31] Recently, generalized joint hypermobility syndrome (HMS) has been defined as a clinical syndrome that can be identified only through differential diagnosis of the above named conditions. It is characterized by joint laxity and excessive range of joint motion associated with musculoskeletal pain in the absence of rheumatological inflammation.[25] Kirk and his colleagues[26] named the pathology, which led to the development of specific criteria by Carter and Wilkinson[31] to diagnose the condition. In 1969 Beighton, Solomon, and Soskolne[24] fine-tuned the diagnostic criteria to create the most widely utilized screening tool for HMS.[19,21,23-26]

Generalized joint hypermobility syndrome affects as many as 17.5 million Americans or 4% to 7% of the population, but the majority of people are unaware that they have the syndrome.[25,29,30] One of the reasons HMS has been underdiagnosed in the general population is because it has previously been considered to be a harmless idiosyncrasy. However, it has been discovered to be associated with many painful and debilitating joint conditions: degenerative joint disease, recurrent dislocations, arthralgia, recurrent effusions, traction injuries at tendon or ligament

insertions, synovitis, joint instability, decreased efficiency of the sensory proprioception feedback, and even ligament sprain or rupture.[19-37] There are other varied reasons for the underdiagnosis of the syndrome. Clinical training tends to focus on decreased, rather than excessive, range of motion so clinicians are not as likely to diagnose the syndrome. The pain associated with HMS can usually be self-managed by limiting activities, which means those afflicted the syndrome may not seek medical attention in the first place.[25,29] The musculoskeletal symptoms and pain associated with HMS can strike at any age, but they are usually more frequent during adolescence, so HMS has previously been misdiagnosed as "growing pains" or even "neurosis" instead of hypermobility of the connective tissue.[25,26] Since generalized joint hypermobility has been underdiagnosed, it follows that it has been underestimated as a cause for injuries.

Generalized joint hypermobility syndrome is thought to be an inherited connective tissue disorder of collagen, especially in the ligaments and the joint capsule.[25,31] There has been a strong familial component to the incidence of HMS, and several studies speculate as to whether the inheritance of this connective tissue disorder could be autosomal dominant, autosomal recessive, or a sex-influenced dominant trait.[19-25] A study by Child[20] found that the majority of patients with symptoms of HMS had a family history of joint hypermobility and/or early onset joint pain.[19-22,25-27] The exact mechanism of inheritance has yet to be determined, for it is extremely complicated. Many of the most respected experts in the field of connective tissue dysfunction while at a conference of human genetics in 1986 could not reach a consensus to establish discrete categories of the various hypermobility syndromes.[25] In fact, distinctly separate clinical disorders of connective tissue were found to result from defects in the exact same gene.[25] The current theory is that hypermobility is

determined by a dominant trait with sex-influenced phenotypic manifestations, with females more severely and more often affected than males in the same family.[25]

Connective tissue is primarily composed of collagen, which is a complex rope-like macromolecule that gives tendons, ligaments, and joint capsules their mechanical ability to stabilize skeletal joints.[25,32] Those with HMS have been shown to have a significant imbalance in the two most prevalent collagen types. By using electron microscopy, Child[20] also found that the majority of patients with HMS have an abnormally small proportion of the stronger and more mature type I collagen and an increase in the extracellular matrix cells including type III collagen, elastin, and fibrocytes.[25-26] This indicates a disturbance in collagen metabolism, which likely is the reason the tissue tends to be weak, extensible, and easily injured.[20,25]

Even with the longstanding interest and recent surge of research on the subject of HMS, there is uncertainty about the pathophysiology and the risk factors of hypermobility.[25] Physical therapists are concerned with answering these questions due to their involvement of the management of the syndrome and the associated secondary diagnoses. One of the major risks which has been identified is osteoarthritis, which is due to the decreased effectiveness of the collagen and leads to "wear and tear" arthritis.[20]

The most recent studies of HMS have looked at the manner in which the collagen deficiency affects the competency of sensory receptors.[33-36] Sensory feedback, specifically the proprioceptive and kinesthetic information, is used by the central nervous system to monitor the position and movement of joints.[34] A decreased awareness of joint position is believed to be a prevalent cause of injury.[34] Those with generalized joint hypermobility have reduced accuracy in joint awareness and reduced firing of these receptors.[34] Hall and colleagues[35] also found that HMS subjects showed a lack of the appropriate increase in sensory firing at five degrees of

flexion. Consequently, at near full extension of the knee, those with HMS experienced movement sensation similar to that in midrange. In normal subjects the proprioceptive feedback of the last 5 degrees of knee extension typically triggers the protection mechanism by relaying the proprioceptive information to the central nervous system. The current hypothesis is that this defect in kinesthetic awareness, which is due to the defects in the ligament and capsule structural connective tissue, is an obvious deficiency in the protection against traumatic injury.[34-35]

The features of joint hypermobility and laxity have been found to be more prevalent in women.[19-43] Hypermobility is a general term, which can be applied to excessive joint motion due to ligaments, the joint capsule, or even a fracture; whereas, laxity is reserved for ligaments. In the literature, laxity and hypermobility are sometimes used interchangably even though the research has found at best a weak correlation of the two variables.[43] Larsson and colleagues[23,28] conducted two powerful research studies to begin to collect data on the epidemiology of HMS. While studying 660 American musicians, the ratios for the occurrence of 3, 4, and 5 features of HMS were 4:1, 8:1, and 3:1, respectively.[23] A subsequent study of 606 Swedish industrial workers confirmed a statistically significant higher prevalence of HMS syndrome in females, even though a slight ethnic variation was noted.[28] Also, an extensive study by Bulbena et al[39] which evaluated hospital patients using the three major hypermobility scales in order to determine interrater reliability, concurrent validity, and predictive validity found acceptable levels for reliability and validity. It was also re-emphasized that women have a significantly higher prevalence of hypermobility of joints, and it was suggested that "it may be appropriate to set the cutoff point for men one point below the level of women."[39] However, none of these studies examined whether those with HMS were more likely to have joint injuries.

It is perhaps not a coincidence that women also have higher prevalence of anterior cruciate ligament injures. The many studies regarding ACL injury are consistent in establishing that females are more prone to injure the ACL, especially while participating in sports such as basketball.[2,4,7-10,12,15-16] A study by Malone[8] reported that collegiate female basketball players were eight times more likely to sustain ACL injury compared with collegiate male basketball players. In addition, NCAA surveillance, after analyzing five years of data, found the specific ACL injury rate in women basketball players to be more than 4 times that of the male players.[7,12,15] For the 1989-1990 season, the rate of female ACL injuries was 7.8 times that of the males.[15] Emerson[4] found that women are more than 6 times more likely to injure an ACL. The study by Gray et al[12] at the British Columbia Sports Medicine Clinic recorded that 72% of the women's sports-related injuries involved the knee, and 35% of these knee injuries were ACL ruptures. The authors concluded that ACL rupture appears to be an injury to which adolescent female basketball players are especially predisposed, as the incidence at the clinic was five times that of the males.[12]

There are a few other factors that support the hypothesis of a correlation between HMS and ACL rupture. The typical patient to present with the musculoskeletal pain of HMS is an adolescent female between 10 and 15 years of age. This age range overlaps with the findings of Angel and Hall[40] who have described that the most likely age for an ACL rupture is 14.3 years of age with a range of 8 to18 years.[12,40] A hereditary component has been found in ACL injury as has been with HMS.[40] Harner et al[41] found those with an ACL rupture were significantly more likely than the control group to have an immediate family member who also sustained an ACL rupture. Another interesting finding is that the most common HMS-symptomatic joint is the knee.[33,42] Forty six percent of people in a

study of the clinical population of HMS at the University of Rochester were found to have musculoskeletal symptoms at the knee joint.[42]

Preventing and improving treatment for an ACL injury are the goals for orthopedic medical professionals such as physical therapists. These goals can only be reached with a clear understanding of the functional anatomy and the injury mechanism of the ACL. When a ligament is taut, it is able to perform its natural functions of guiding joint motion and preventing excessive motion. HMS seems to decrease the efficiency of the ligament in performing these functions. The ACL originates at the lateral femoral condyle and runs distally, anteriorly, and medially to insert on the tibial plateau. The multiple collagen bundles that compose the ligament interconnect in a nonparallel fashion, fan out to cover a broad flattened area at both attachments, and can be separated into three distinct bundles.[32,43-45] Because of the ACL's orientation, a different portion of the ACL is taut and functional throughout the entire range of motion.[2,44] The posterolateral bundle is most taut in extension, while the anteromedial bundle is most taut in flexion. The intermediate bundle assists in anterior and anteromedial stability. The whole ligament functions to prevent anterior displacement of the tibia on the femur, knee hyperextension, and excessive internal or external rotation of the tibia. Since a ligament is most likely injured when it is on stretch, it follows that the ACL is most commonly sprained or ruptured during rotation of the tibia in relation to the femur with or without hyperextension of the knee. Basketball players are repeatedly in this position during jumping, cutting, and pivoting maneuvers, and they are in the high-risk category for ACL injury.[2,4,-10,12,15-16]

Some studies have found the incidence of knee injuries to be correlated to increased laxity or hypermobility, but it remains a controversial issue.[16-17,33-58] Nicholas[16] found that loose-jointed professional football players were much more likely to rupture knee ligaments than the tight-jointed players. Using radiograph

imaging, Sturup et al[46] examined 17 patients who had undergone meniscectomies and 10 control subjects for anteroposterior and varus-valgus laxity by calculating the mean displacement of the condyles and of the joint space, respectively. It was found that those who had undergone medial meniscectomies had considerably greater anteroposterior mobility, and so the authors concluded that "idiopathic hypermobility seems to predispose athletes to medial meniscus injuries." A study by Lysens and colleagues[47] found a correlation of ligament sprains and ligament laxity while evaluating 138 physical education students. Malkolf et al,[48] by measuring laxity with an apparatus much like the KT-1000, noted similar laxity between males and females except that females had more laxity during extension of the knee.

In contrast, other studies have found no correlation of excessive motion with injury.[49-55] Grana and Moretz[50] found that ligament laxity did not predispose athletes to injury. Godshall et al[51] found that a preparticipation screening of ligament laxity and hypermobility was not predictive of injuries in his sample of subjects. Also, Kalkenek and Morehouse[52] suggested that it is not cost-effective for exercise programs to be based on the presence of joint laxity.

The researchers who attempt to describe this increased ACL injury rate in females seem to cover the gamut of possible theories, which can be divided into the two main categories of personal and environmental characteristics.[1-16,34-36,38-68] The most likely hypothesis is that the cause of ACL injury is multifactorial, with some factors weighing more than others.[58] A summary of the various theories will follow. Some of the personal characteristics are attributed to the inherent anatomical and structural differences between genders including body composition, intercondylar notch width index (NWI), lower extremity alignment, muscle strength, and joint laxity.[1-2,7-10,12,14-15,33-43,45-68] Other personal characteristics age, physical fitness, previous injury, psychosocial characteristics. The environmental characteristics

include the type of sport (rules, playing time, position, level of competition, and protective equipment), facilities (playing surface, weather, time of day or season), and/or coaching and training.[1,7-10,12,14-15,38,43,45-68]

A study by Drinkwater[59] emphasized that the percent body fat and overall body composition is more heterogeneous between different sports than between genders. Also, Whiteside[11] and Clark et al[13] independently concluded that there was a greater similarity in body composition and athletic injury in the same sport regardless of gender. The intercondylar notch, which is at the femoral attachment of the ACL, has also been implicated as a cause for ACL injury.[60-63] In general, females have a smaller notch width index (NWI) and a smaller ACL.[60] A few studies found that smaller notch size and ligament size were associated with increased risk for ACL injuries.[60,61] However, LaPrade and Burnett[61] found no gender difference in notch width index and rate of ACL injury.

The alignment of the female's lower extremity has been implicated in athletic injuries, especially of the knee, even though little data supports this theory.[7] Females generally have increased genu valgum, femoral anteversion, and external tibial torsion leading to a more lateral pull of the quadriceps muscles at the knee, which is believed to cause patellofemoral problems.[7,12] A study by Gray and colleagues[12] while measuring female basketball players found no apparent relationship between the tibiofemoral alignment and knee injury, particularly ACL injury.

Another lower extremity alignment problem that may be involved in ACL injury is subtalar joint hyperpronation. The female foot is more flexible, allowing more talar motion and forefoot pronation, which can be assessed by observing the calcaneal or the navicular alignment. Woodford-Rogers et al[18] looked at navicular drop, calcaneal alignment, and anterior knee joint laxity with a KT-1000 in 44 athletes over a two-year period. The data suggests that greater pronation and greater

anterior knee joint laxity are associated with ACL injury. Beckett et al[46] also found a relationship between hyperpronation and ACL injury. However, as the authors concluded, more studies are needed on this topic to provide conclusive evidence of the relationship.

Strength is another personal characteristic which may account for some of the gender difference in ACL injury. In general, female muscle tissue does not differ significantly from its male counterpart in potential for force output.[64] Wilmore[65] studied 47 women and 26 men after a 10-week weight training program. He found slightly higher relative strength in males for the upper extremity and a slightly higher relative strength in females in the lower extremity was calculated when lean body mass was taken into account.[65] Eccentric hamstring strength is arguably one of the most important factors in protecting the ACL because these muscles help prevent anterior translation of the tibia on the femur. Moore and Wade[66] found that the hamstring-to-quadriceps strength ratios in women were less than that of the men.[66] In a well-controlled research study with 140 college elite and amateur athletes, Huston and Wojtys[9] found that the female athletes' decreased hamstring-to-quadriceps strength ratio created a tendency for them to rely on their quadriceps to stabilize the knee, and this muscle imbalance in female athletes differed from the males and the female non-athletes.

Neuromuscular performance by the dynamic muscle stabilizers of the knee has an important role in injury prevention, and it has been implicated as one of the gender differences that may account for this discrepancy in ACL injury rates. As Huston and Wojtys[9] found that female athletes had a tendency to use quadriceps initially to stabilize the knee and that the hamstrings were activated significantly later. This neuromuscular method of stabilization has the potential to cause a strain on the ACL. Also important in the neuromuscular system's attempt to prevent injury is the

response time required to generate peak muscle torque once the protective muscle contraction has been initiated. The females in this study required significantly more time than the males to produce the same relative muscle force, especially in the hamstring muscles. These are areas for further study, but it is interesting that these characteristics in the female athletes differed significantly from the three other groups because it again leads to the possibility of a training issue. Another consideration from this study by Huston and Wojtys[9] is that the females had significantly more knee ligament laxity.

More research on the increased female ACL injury rate is necessary in order to lead to better prevention and treatment. The weight of these gender differences is still inconclusive. The female sport programs have been accused of creating players that are less experienced, and there is much research that needs to be done as these new participants may be more susceptible to ACL injuries.[1-2,4,7-10,12,14-15,43,45,47,56-58,67] Females may have less access to adequate facilities, coaches, athletic trainers, and equipment, all of which contribute to a lack of appropriate motor skill and strength, ultimately leading to an increased injury rate.[58,67] The various training methods and athletic experience have been implicated, but these are variables which are more difficult to control, and thus, more difficult to study. It is also still unknown how much each of these environmental factors weigh in the equation of increased ACL injury for female athletes. Current research suggests that the physiologic demands are becoming more similar for the genders in comparable sports, including distance covered and exercise intensity so it may become easier to isolate the specific variables.[13,68]

The management of an ACL injury is also being researched and continually refined. Good treatment always begins with accurate diagnosis. Utilization of the KT-1000 seems to have greatly enhanced accuracy of ACL injury diagnosis.[40,69-74]

The KT-1000 has been described as noninvasive, portable instrument utilized to measure anterior-posterior (AP) laxity of the tibia in relation to the femur by using two components which sense knee motion.[40,72] One of the sensors is placed at the patella, and the other rests on the tibial tubercle.[40] The relative laxity can be measured by recording the displacement between the two sensors.[40] The compliance index, an indication of the connective tissue structures resisting displacement, is calculated by evaluating the difference between the 15 lbs. and the 20 lbs. anterior excursion force.[72] The difference of each individual's right and left compliance indexes for a noninjuried subject would be less than 1 mm.[72] If the right-to-left difference was greater than 3 mm the likelihood of an ACL injury in that individual is very high.[72] Wroble et al[69] studied right-to-left differences in knee laxity using the KT-1000 and found it to be reliable within installations, between installations, and between days. In a study of five different arthrometers, the KT-1000 and the Stryker were found to have the highest diagnostic accuracy.[70]

Long-term follow-up by Shelbourne et al[71] after the accelerated program of physical therapy with 209 patients approximately two to six years after the ACL repair using the KT-1000 has found no long-term affects on stability. Shelbourne and Nitz[75] are well-known for publishing an accelerated ACL rehabilitation program that has greatly affected most of the physical therapy rehabilitation protocols. It was developed because of athletes who refused to be compliant with restrictive guidelines in therapy. These athletes have helped to improve the rehabilitation process, and hopefully studying athletes will also provide the key to determining the cause of ACL injury. With more accurate knowledge of what causes the injury, orthopedic medical professionals can improve treatment for everyone affected with an ACL sprain or rupture.

CHAPTER 3

METHODOLOGY

Sixty female high school seniors from eight northeastern North Dakota and northwestern Minnesota high schools were selected to participate in this study. Guidelines were established and a participant survey was approved by the Institutional Review Board at the University of North Dakota. Participation was on a voluntary basis contingent on parental consent and approval from their respective high schools. A survey, consent form, and a self-addressed stamped envelope were sent to each eligible participant (see appendix). The survey form required the completion of open-ended questions regarding knee injuries that might have occurred during the previous year, either during basketball or another activity. Selection criteria for the study consisted of prior testing by Hawbaker[43] for medical history, hypermobility, and knee ligament laxity; either prior or present involvement in basketball; and participation in the one-year follow-up survey by Didier.[67] Exclusion criteria included any knee injury prior to the hypermobility and ligament laxity testing.

The previous research from Hawbaker[43] and Didier[67] are important to understanding the methods of this study. Each participant was evaluated with the KT-1000 knee ligament arthrometer (MEDmetric Corp. San Diego, CA) to quantify the degree of ligament laxity by Hawbaker.[43] The procedure followed the standard protocol described by Daniel and collegues.[70,72-74] Three trials with the ligament arthrometer at each of 15 lbs (67N) anterior displacement, 20 lbs (89N) anterior

displacement, and 15 lbs (67N) posterior displacement were recorded for each participant. This calculation provides a more accurate representation of the laxity.[72]

The Beighton[24] hypermobility scale was utilized to determine whether the participant could be diagnosed with generalized joint hypermobility syndrome. The testing maneuvers were passive opposition of either thumb to the flexor aspect of the forearm, passive hyperextension of either fifth finger greater than 90 degrees, hyperextension of either elbow greater than 10 degrees, hyperextension of either knee greater than 10 degrees, or the ability to place one's hands flat on the ground while in a standing position with the knees fully extended. A point was given for a positive finding for each side of the body with the scores ranging from zero to nine.[43] The participant was said to have HMS if four or more of the nine joints tested were hypermobile.[43]

The sample was divided into two groups based on hypermobility. Those who had Beighton scores less that four were considered to have normal mobility ($n_1 = 28$). Thirty-two of the participants had a score greater than 4 ($n_2 = 32$). Data analysis was conducted using SPSSXtm (SPSSX[tm] Inc. 444 N. Michigan Ave., Chicago, IL 60611). Significance was set at the .05 alpha-level.

CHAPTER 4

RESULTS

Thirty-two of the eligible students returned the survey. This response rate was acceptable (53%), but it was not ideal. Two knee injuries were reported since the follow-up survey from the previous year. One athlete sustained an apparent mild collateral ligament sprain, and one athlete was treated for an ACL rupture. This is the only ACL disruption that occurred for this sample during the injury-tracking time. A total of 8 knee injuries were reported for this two-year period. Four of the eight occurred during basketball, and 6 of the eight were reported in hypermobile subjects.

The joints which were identified as hypermobile in the sample group were similar to the general population with HMS in that knees and ankles were the most commonly affected. However, the prevalence was much higher than that of the general population. Thirty-two of the sixty subjects who were originally tested had scores that indicated that they possessed hypermobility, which means that 53.3% had HMS, compared with 4% to 7% in the normal population. The compliance index difference of the sample was found to be slightly higher than normal (</= 1 mm), but it was less than pathological laxity (>3 mm). This could be because of the abnormally high percentage of HMS subjects in the sample. A general trend appeared in the data for those identified with generalized joint hypermobility syndrome to have higher KT-1000 values.

The correlation value between hypermobility and knee injuries could not be determined due to the low number of injuries and the high sensitivity of the Chi-square. However, it is worth noting that the ACL rupture occurred in a hypermobile

subject and the injury followed the classical mechanism of injury (which is the noncontact deceleration maneuver). Also, it is interesting to note that of the total number of injuries, 75% occurred in those who were hypermobile compared with 25% in those who had normal mobility.

An independent sample t-test was used to analyze the correlation between knee ligament laxity as measured by the arthrometer and the number of knee injuries. The mean compliance index, which was calculated by averaging the right and left compliance indices, was determined to be 1.4 in the uninjuried group and .92 in those who sustained knee injuries. The statistical difference between groups was determined to be $p = .053$, so it cannot be considered significant. The general trend was for those with knee injuries to be less lax than those who were uninjured.

CHAPTER 5

DISCUSSION

The results of this study were interesting, but the real potential was not reached. The main limitation in this study was that the sample size was too small to make the findings statistically significant. Again, there was only one ACL injury reported, and even though it was sustained in a subject possessing generalized joint hypermobile syndrome, this is not enough evidence to assert any conclusions for the relationship between the two. Since the low response rate decreased the sample size that was available for data analysis, achieving statistical significance was more difficult. Also, it is unknown whether any of the subjects who did not respond sustained knee injuries.

The study was also limited due to the self-reported nature of the injury survey. Athletes might not know their specific diagnosis. They may rely on their own knowledge or their coach's knowledge to diagnose their injury rather than that of an orthopedic medical professional. If the athlete visited an orthopedic medical professional, they may not remember the specific diagnosis. Therefore, the description may not accurately represent the actual injury sustained. The author had planned to interview each athlete individually along with the survey in order to gain more specific information regarding the subject's perception of any injury that was sustained. However, a regional flood cut the survey response time short, and the interviews were not able to be completed.

Another limitation of the study is in the inability to control for the additional personal and environmental characteristics which may have played a role in the

incidence of injury. As stated before, training, coaching, and the playing conditions probably play a role in the likelihood of injury.

This study was able to further delineate that generalized joint hypermobility syndrome and ligament laxity may not be synonymous since it was found that the majority of those with injuries were hypermobile, but they were also generally less lax than those who did not sustain any injury.

CHAPTER 6

CONCLUSIONS AND CLINICAL IMPLICATIONS

A larger sample size with an even longer tracking period would increase the power of the study and help to achieve statistical significance in a correlation between ACL injury and generalized joint hypermobility syndrome. A suggestion would be to establish a continual program of testing sophomore or freshman basketball players for generalized joint hypermobility syndrome and laxity and to also continually monitor the injuries that occur. The larger sample size would help in achieving statistical significance in a correlation between ACL injury and hypermobility.

Since ligament laxity does not seem to have the assumed direct relationship with hypermobility, it will be important for future studies to continue to address clear and specific definitions for laxity and hypermobility. The results could then be compared more easily. Future research on this topic of female predisposition to ACL injury should take into account the findings of other researchers. These findings include the significant neuromuscular difference in dynamic stabilization of the knee between elite male and female athletes, the increased laxity in females, and the difference in proprioception for those with HMS.[9,18,32-43] Future researchers should also address reliability and validity issues. If the environmental factors including training, coaching, and sport exposure could be controlled, it may lead to better prevention and treatment of ACL injury. Also, the reliability of the KT-1000 and other arthrometers has yet to be proven conclusively, and the validity of the Beighton hypermobility test as the most accurate predictor of HMS is, as yet, inconclusive.

APPENDIX

__EXPEDITED REVIEW REQUESTED UNDER ITEM __ (NUMBER[S]) OF HHS REGULATIONS
__EXEMPT REVIEW REQUESTED UNDER ITEM ___ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA
HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Jan Gustafson **TELEPHONE:** (701) 777-9780 **DATE:** 1/27/97

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: Physical Therapy Department

SCHOOL/COLLEGE: UNDSOM **DEPARTMENT:** PT **PROPOSED PROJECT DATES:** 3/1/97 - 5/31/97

PROJECT TITLE: An Analysis of Generalized Joint Hypermobility as Related to Knee Pathology

FUNDING AGENCIES (IF APPLICABLE): _____

TYPE OF PROJECT:

X NEW PROJECT __ CONTINUATION __ RENEWAL _ DISSERTATION OR THESIS RESEARCH X STUDENT RESEARCH PROJECT

__ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Mark Romanick

PROPOSED PROJECT: __ INVOLVES NEW DRUGS (IND) __ INVOLVES NON-APPROVED USE OF DRUG X INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

X MINORS (<18 YEARS) _ PREGNANT WOMEN _ MENTALLY DISABLED _ FETUSES _ MENTALLY RETARDED

_ PRISONERS _ ABORTUSES _ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ___

1. ABSTRACT:

Sixty healthy female high school varsity basketball players have been chosen to participate in this study. The purpose of this study is to determine whether a correlation exists between athletes with generalized hypermobility and knee ligament pathology. Since a positive correlation has been statistically determined between joint hypermobility and right knee ligament mobility in a previous study with these athletes, there is a possibility that this exposes these athletes to greater risks of ligament damage while participating in their sport. A statistical analysis of the participants' injuries as reported on a survey will be correlated with the baseline data to determine if injury risk identification is statistically significant. The knowledge of such a relationship, if any, could be of benefit to athletes.

PLEASE NOTE. Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL.

Sixty healthy female high school varsity basketball players will be asked to complete a survey regarding any knee injuries that have occurred over the last 12 months. This information will be correlated with data regarding generalized joint hypermobility and knee ligament laxity, demonstrated previously in a study with these same athletes, in order to describe any relationship that might exist between knee ligament pathology (injuries) and generalized joint hypermobility.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

This information will be available to athletes and professionals who work with athletes. It may be of benefit to know of any possible relationship between generalized joint hypermobility and knee ligament pathology so that further research can address possible prevention measures that could be helpful for athletes in the future. Also, the participating athletes will have the benefit of knowing that they contributed to scientific research.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

This study should pose no known risks to the participants.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.
Describe where signed consent forms will be kept and for what period of time.

The consent forms will be locked in a file in the UND Physical Therapy Department for two years following completion of the study.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.
For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

_____ **DATE:**
Principal Investigator

_____ **DATE:**
Project Director or Student Adviser

_____ **DATE:**
Training or Center Grant Director

INFORMATION AND CONSENT FORM

An Analysis of Generalized Joint Hypermobility as Related to Knee Pathology

You are being invited to participate in a study being conducted by Jan Gustafson, a student in the physical therapy program at the University of North Dakota, that will evaluate if joint hypermobility (excessive joint mobility) plays a role in knee injury. Healthy female athletes are being asked to participate in this study. The study involves completing a survey about any previous knee injuries. Answering the questions should not take more than 30 minutes of your time and participation is entirely voluntary.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. You are free to discontinue participation at any time. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota.

If you have any questions concerning this study, please contact Jan Gustafson or Mark Romanick at the UND physical therapy department at 777-2831. A copy of this consent form is available to all participants in the study upon request.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to allow my daughter to participate in this study.

_____

Parent or Guardian's Signature Date

I have read all of the above and willingly agree to participate in this study.

_____

Participant's Signature Date

_____

Witness (not the scientist) Date

High School Statement of Participation

The University of North Dakota Physical Therapy Department and Jan Gustafson, student physical therapist, are conducting a study concerning the possible relationship between joint hypermobility (excessive motion) and knee injuries. We would like your consent to gather information through a survey that addresses any knee injuries sustained by the female athletes that have participated in basketball at your high school.

The study will require the participants to complete a survey indicating their level of participation in the female varsity basketball program and any injuries sustained since that time. Subject participation is entirely voluntary.

I understand that by giving permission for _____ High School to participate in the project stated above, I am allowing the survey process to take place at the participating high school. If you have any questions or comments, you can contact either Jan Gustafson or Mark Romanick, advisor, at (701) 777-9780 or (701) 777-2831, respectively.

_____

High School Principal Date

_____

Principal Investigator Date

_____

Student Advisor Date

Participant Questionaire Subject #_____

High School _____ Grade Fr So Jr Sr

1. Did you participate in the 1996-1997 girl's basketball season? Y N
If no, why not?_____

2. At what level of play did you participate? Varsity Junior Varisty
(circle all that apply)

3. On average, how many quarters did you play? _____

4. Please describe any type of injury you had (or have) as a result of your participation in basketball and the approximate date of the injury. If you have had no injuries due to basketball, go to question #8.

_____
Date Injury

_____
Date Injury

5. Did you receive medical attention because of the injury? Y N
If yes, please describe._____

_____

6. Was your playing time restricted because of the injury? Y N
If yes, how long?_____

7. Please describe how the injury occurred._____

_____

8. Have you sustained an injury involving your lower extremity (hip, thigh, knee, ankle, or foot) that was unrelated to basketball in the last 12 months? Y N
If yes, please describe._____

_____

Thank you for your time and consideration.

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